Mountain Pine Beetle-induced changes in Lodgepole Pine needle flammability

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Mountain Pine Beetle Forum

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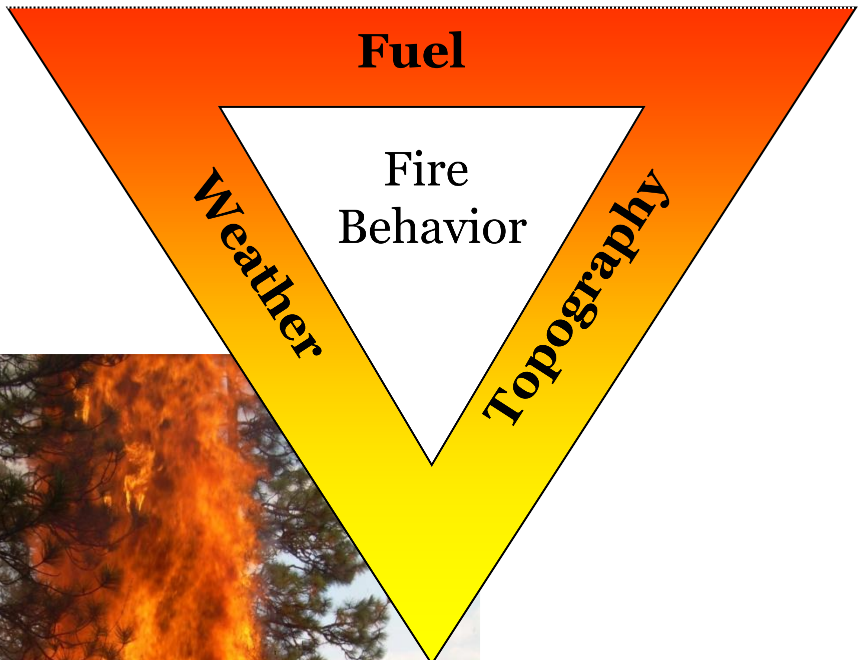
Outline

- Fire Behavior Primer
  - Important factors, types of fires and how they spread
- How beetles alter the fuel characteristics and potentially alter fire behavior
- What are we doing:
  - Examining fuel properties at various stages of attack
  - Testing the foliage flammability
  - Using measurements to simulate single tree fire behavior
- Take home points

What drives wildland fire behavior?



Fuel

- Amount
- Arrangement (Horizontal and Vertical)
- Chemistry
  - Moisture Content
  - Chemical make-up

Weather

- Wind
- Solar radiation
- Temperature / Humidity

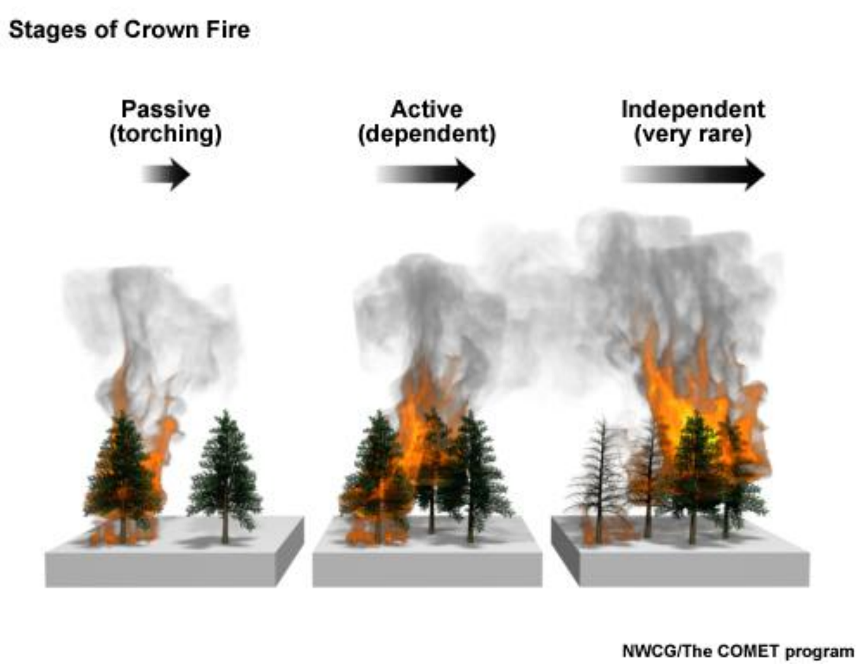
Topography

- Steepness
- Orientation relative to the sun

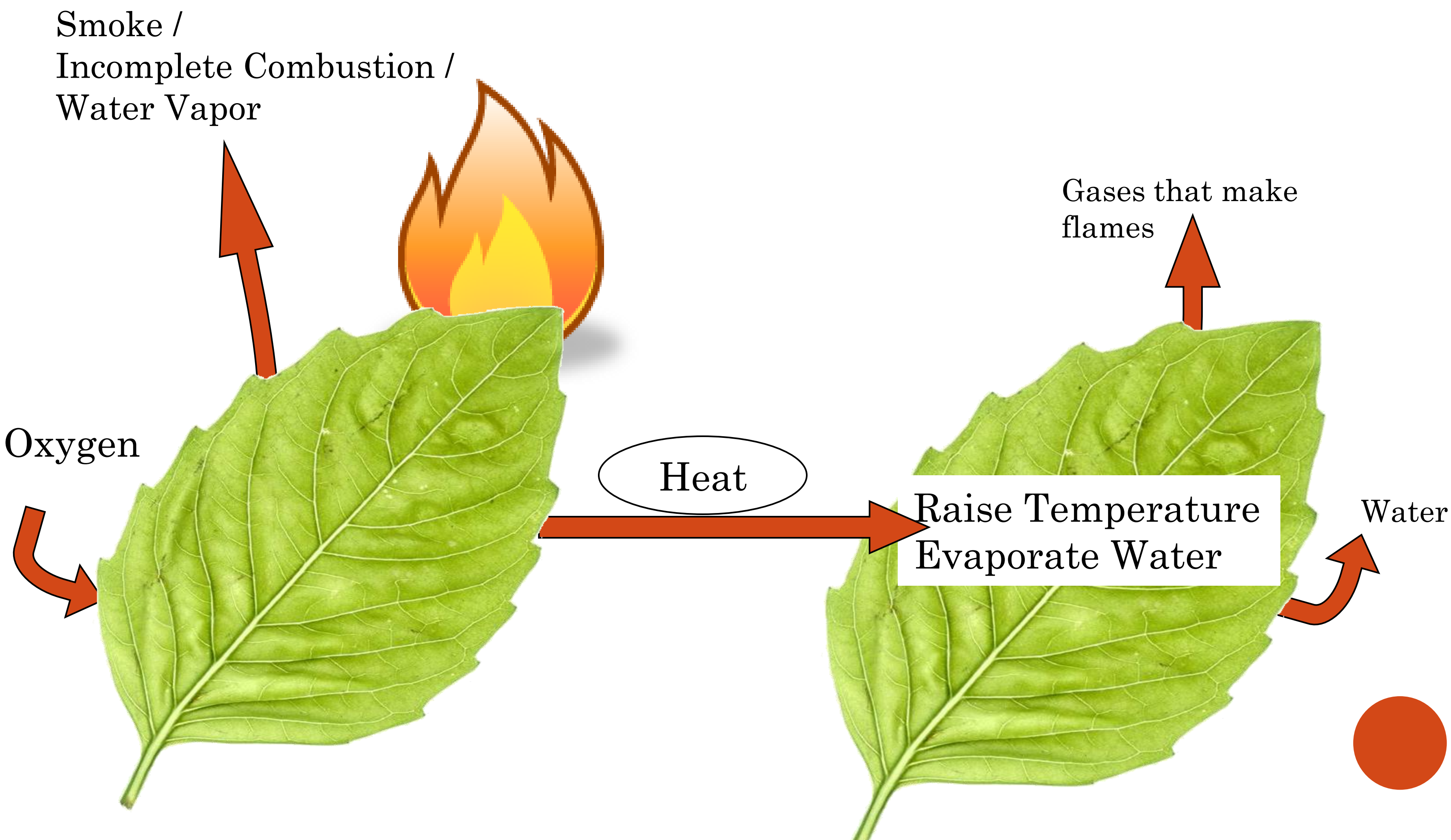
Types of Fires

Fires burn in different strata of fuels:

- Ground fires
  - Organic matter
- Surface fires
  - Litter, logs, grasses, shrubs
- Crown fires
  - Burn in overstory trees
    - Passive (Torching)
    - Active (Dependent or independent of a surface fire)

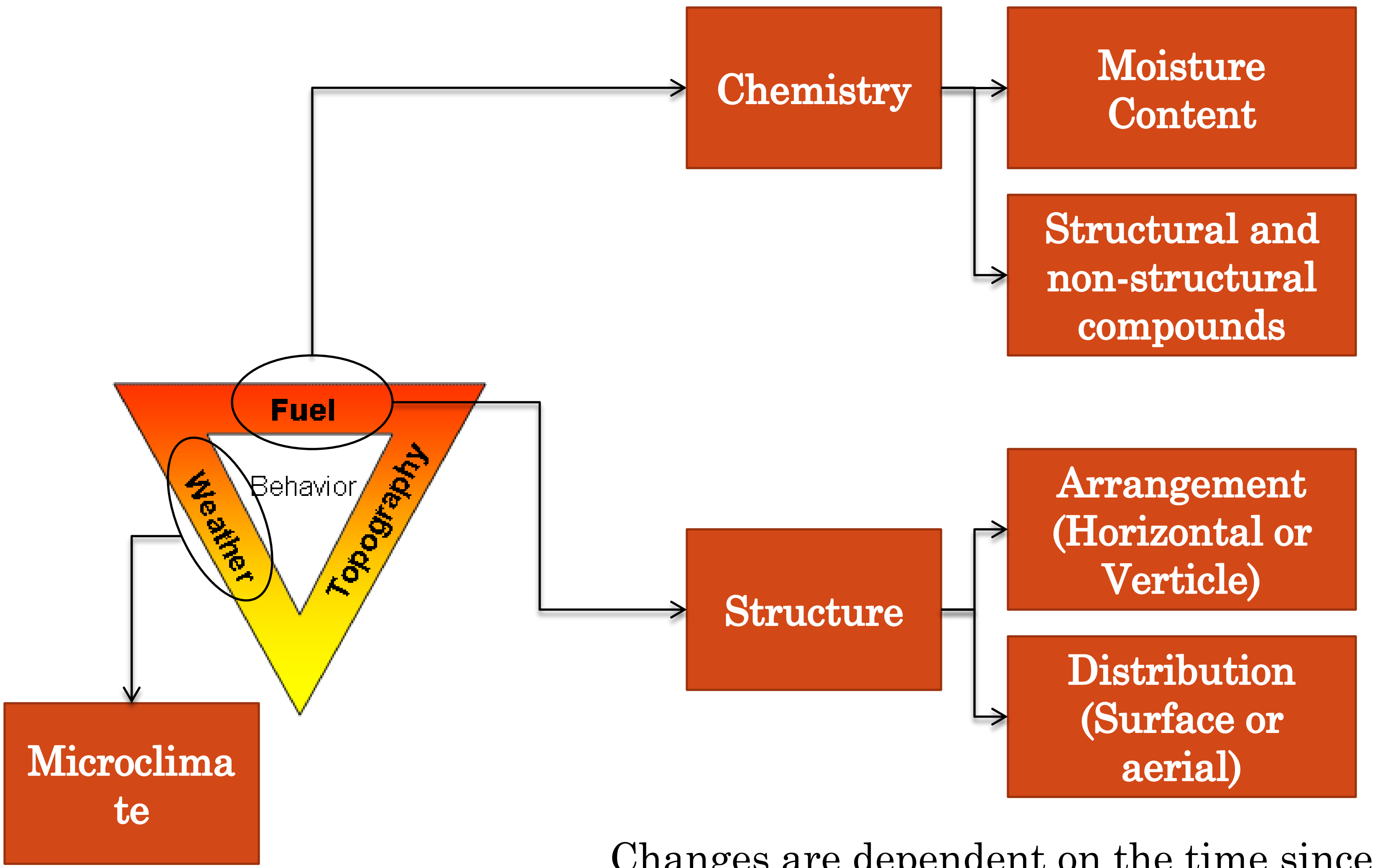


How do fires spread?



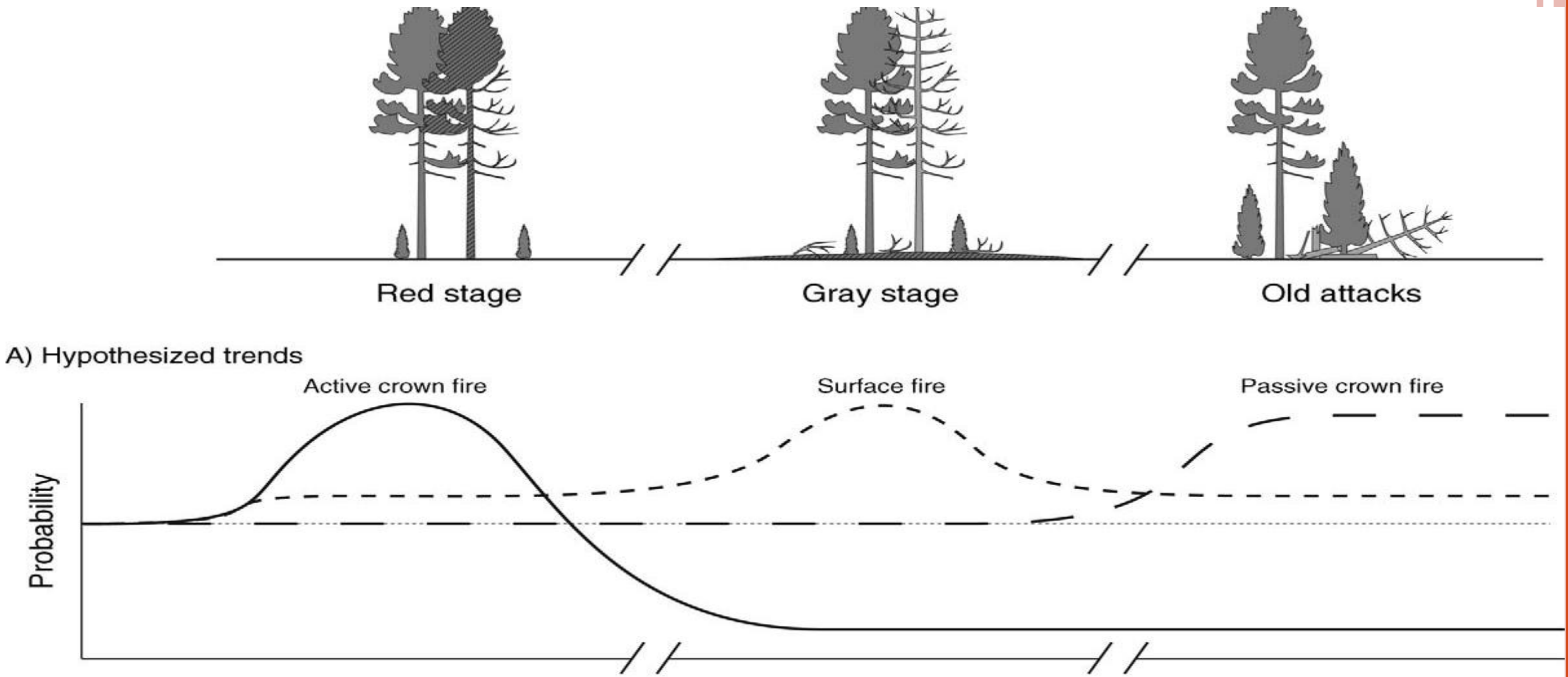
How do mountain pine beetles wildland fuels?

How Mountain Pine Beetles alter fire behavior



Changes are dependent on the time since attack

How might fire be expected to change after a mountain pine beetle attack?



Simard et. al 2011. http://esa.org/papers/pdf/emon-81-01-04_3.24.pdf

Need for this work

- Context: Firefighters and the public are concerned with how fires are going to burn, not the longer-term, ecological perspective
- Current tools for predicting fire behavior are not valid in Mountain Pine Beetle-attacked trees
  - They were developed for healthy green trees
- New CFD-based fire behavior models are better suited for addressing these relationships between fuel alterations and fire behavior
  - We need good fuels information to feed these models to better understand how fires will burn in beetle-attacked stands

Assessing the flammability of Beetle-killed trees

Fuel moisture, chemistry and ignition behavior

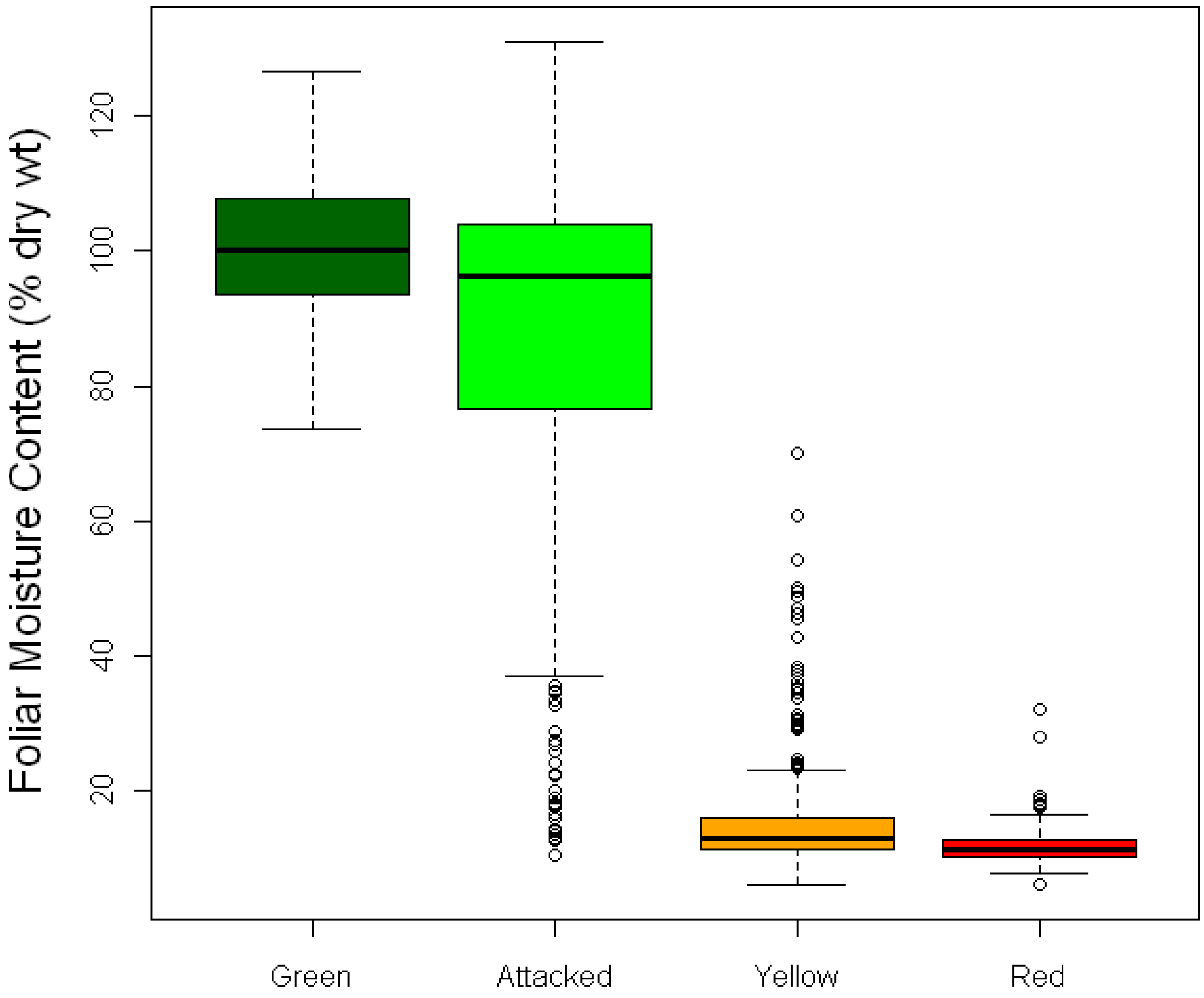
- Starting before green-up in 2010 we selected trees in four distinct groups:
  - Healthy Green
  - Green Attacked
  - Transition (Yellow)
  - Red
- Sampled foliar moisture content, foliar chemistry and ignitability throughout the season

Foliar Moisture Content

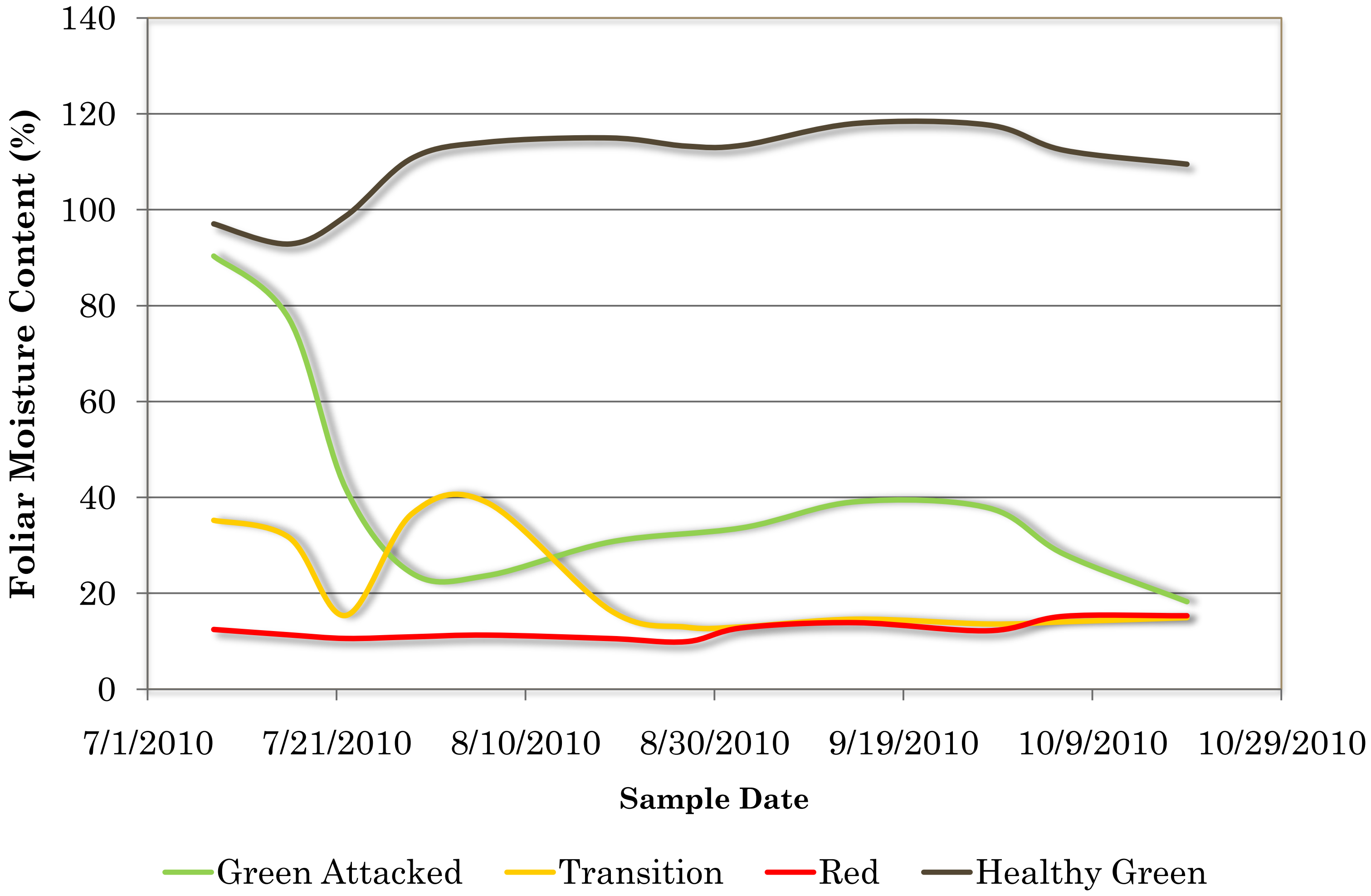
Foliar Moisture Content

- Foliar moisture measured and expressed as a percentage of their dry weight
- Moisture content has long been considered an integral part of the ignition characteristics of fuels and has been show to be an important factor in the ignition of healthy Lodgepole pine
    - Xanthopoulos, G. and Wakimoto, R. (1993). A time to ignition - temperature - moisture relationship for branches of three western conifers. Can. J. For. Res. 23(2): 253–258.

Average foliar moisture content by attack category



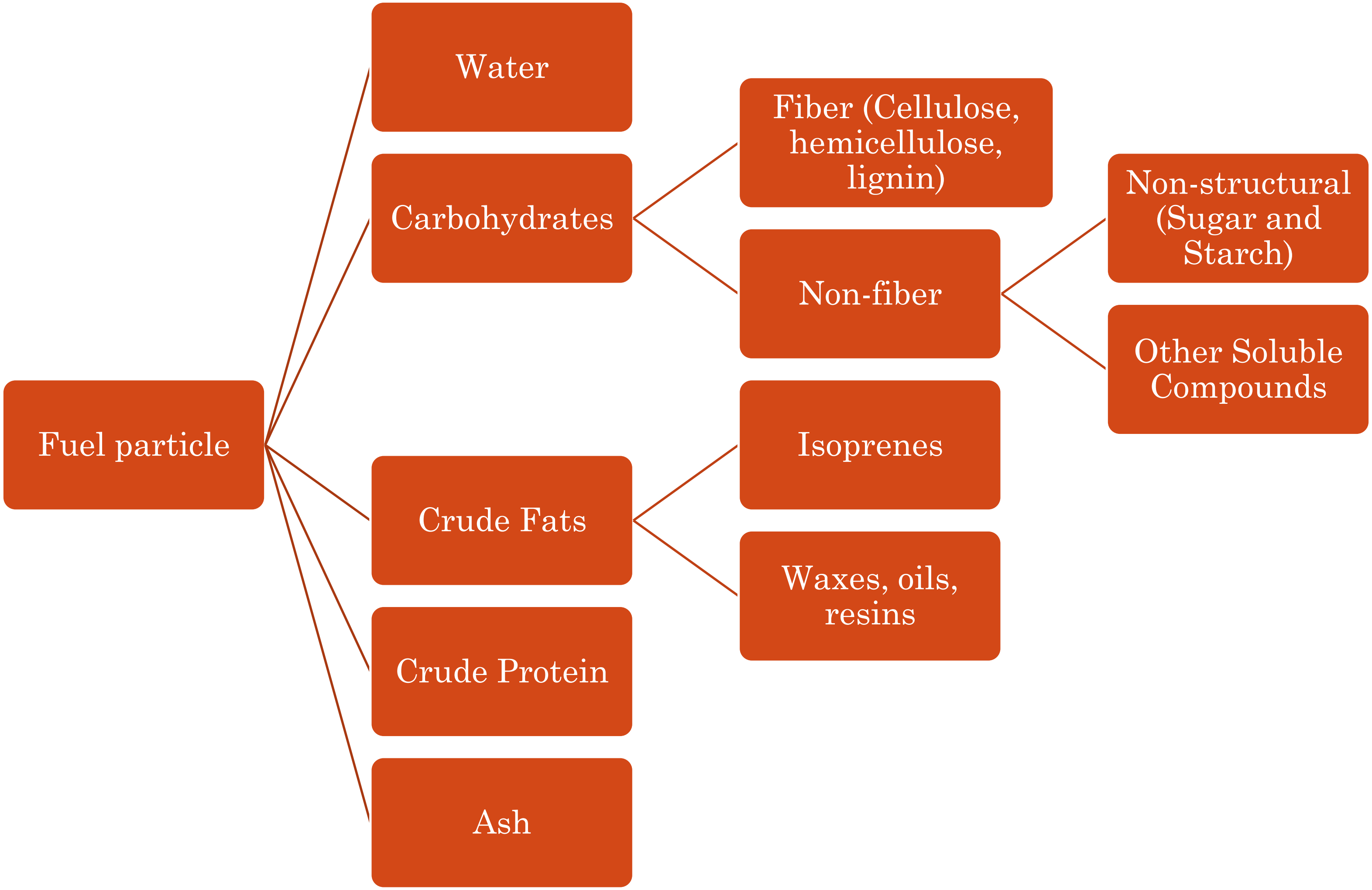
Foliar moistures over time by category



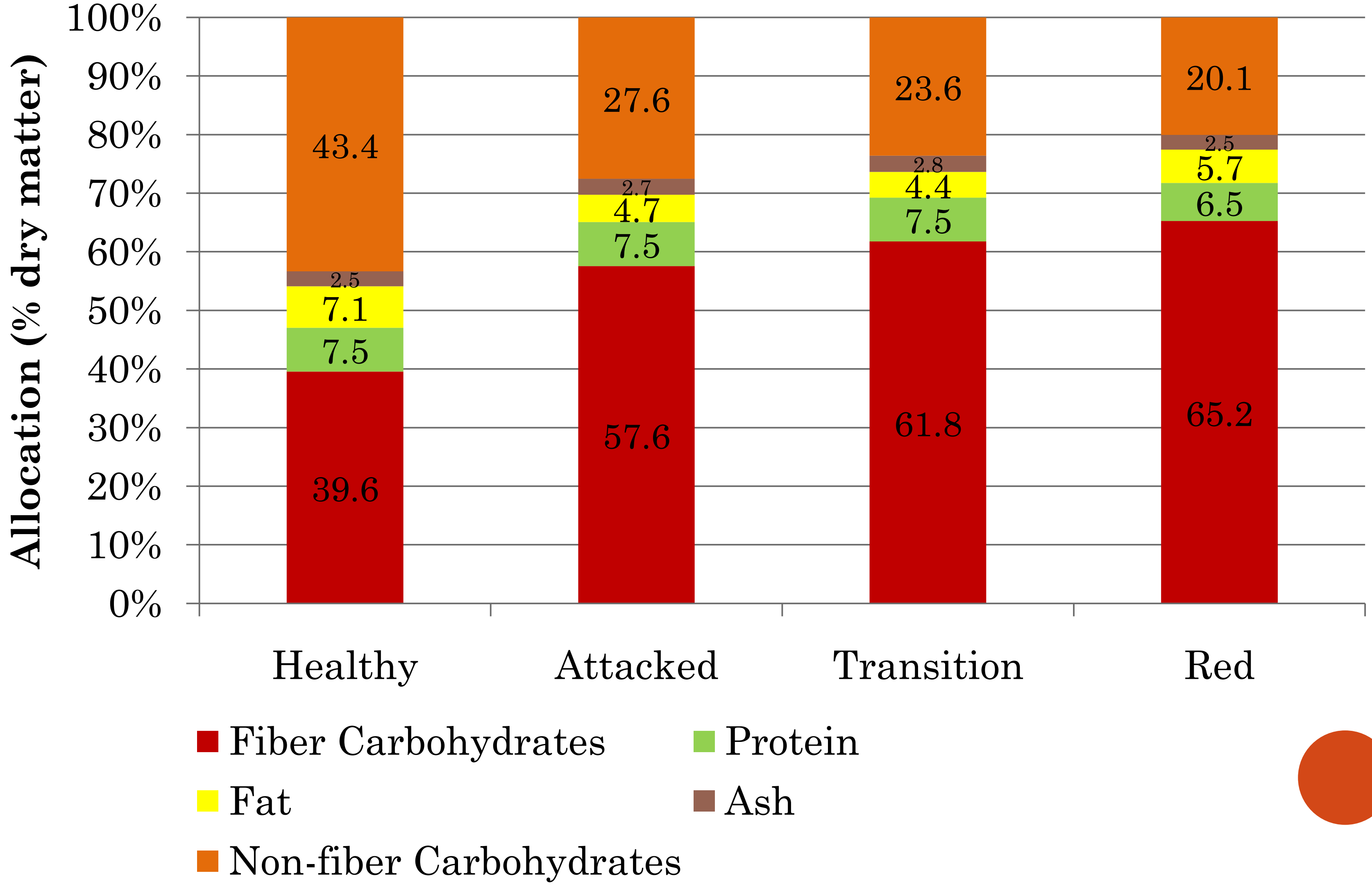
Tree Condition	Seasonal minimum FMC (% dry weight)	Seasonal maximum FMC (% dry weight)	Seasonal average and standard deviation FMC (% dry weight)
Green	81.0	120.3	100.7 (9.2)
Attacked	12.3	125.2	84.6 (30.9)
Yellow	8.4	59.3	16.1 (9.1)
Red	8.1	25.0	11.7 (2.3)

Foliar Chemistry

Foliar Chemistry



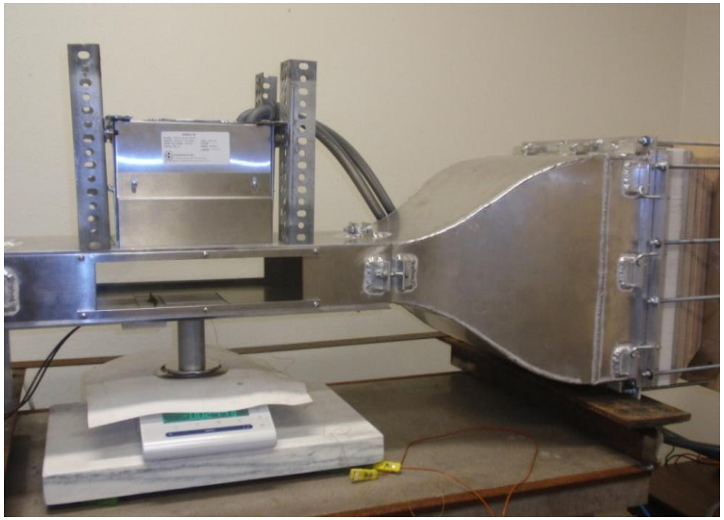
Foliar Chemistry across the four stages of attack



Foliar Flammability

Experiment apparatus: small-scale wind tunnel with high precision balance

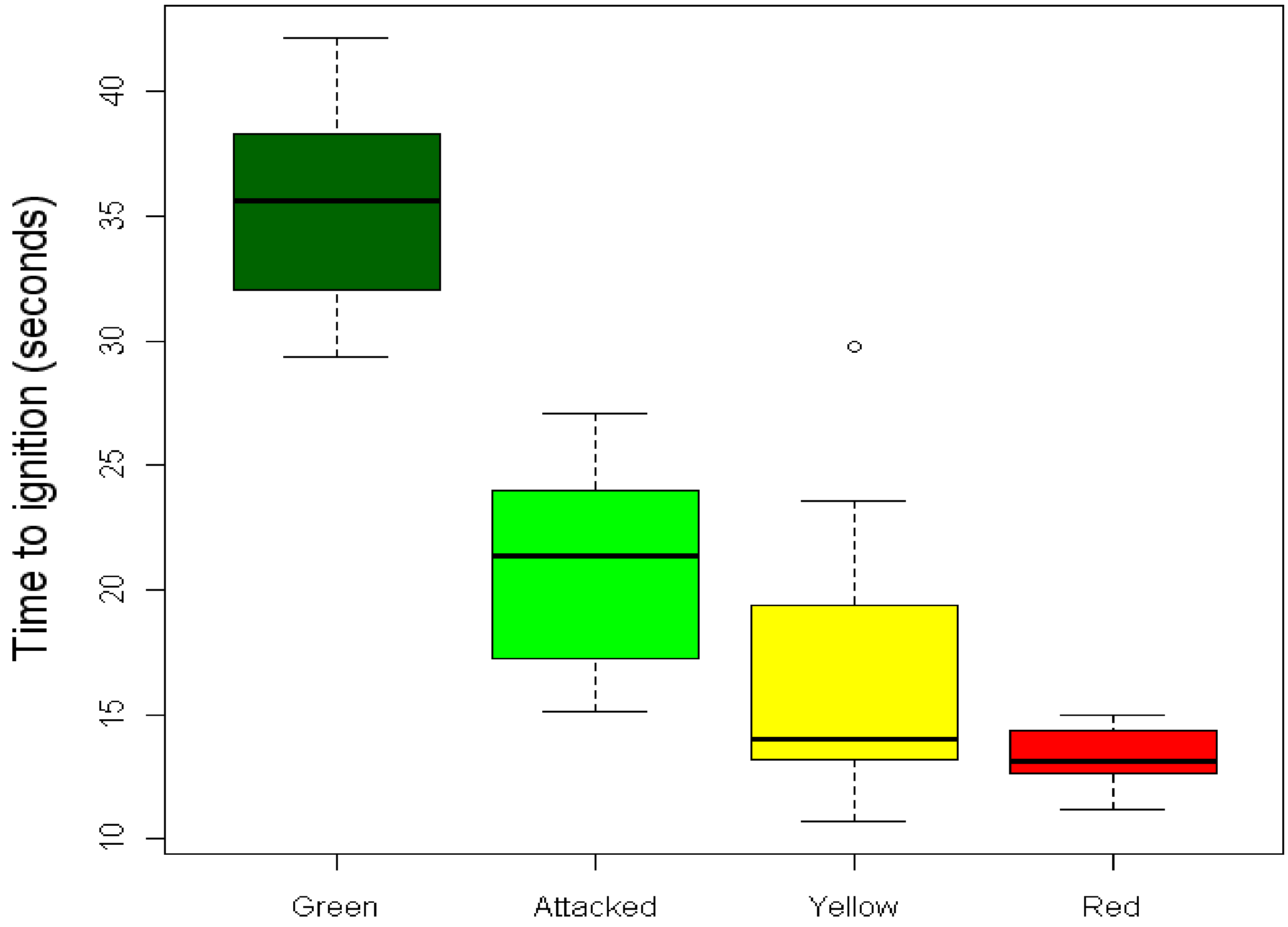
- Based on the Forced Ignition and Flamespread Test (Cordova *et al*., 2001)



Thanks to Dr. Sara McAllister for use of equipment and for photos

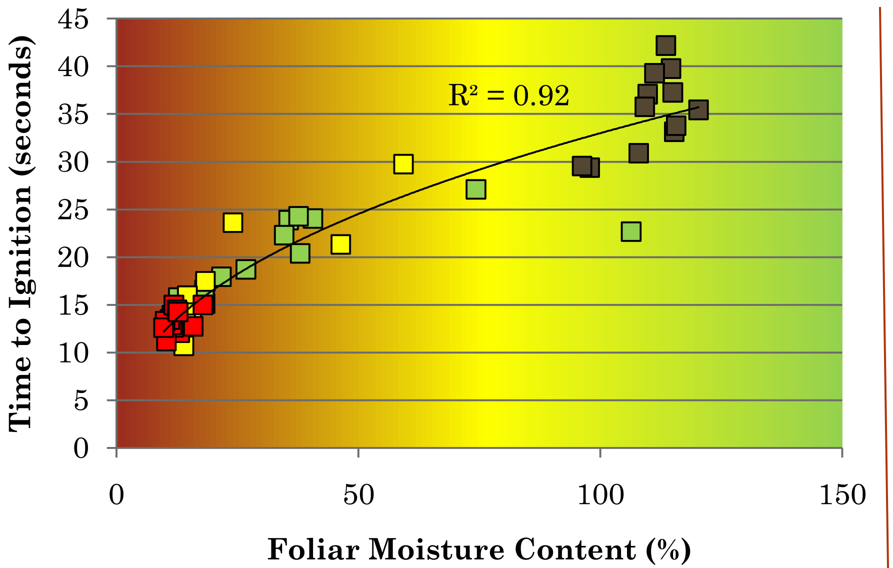
Cordova, J., Walther, D., Torero, J., Fernandez-Pello, A., 2001. Oxidizer flow effects on the flammability of solid combustibles. Combustion Science and Technology 164, 253-278.

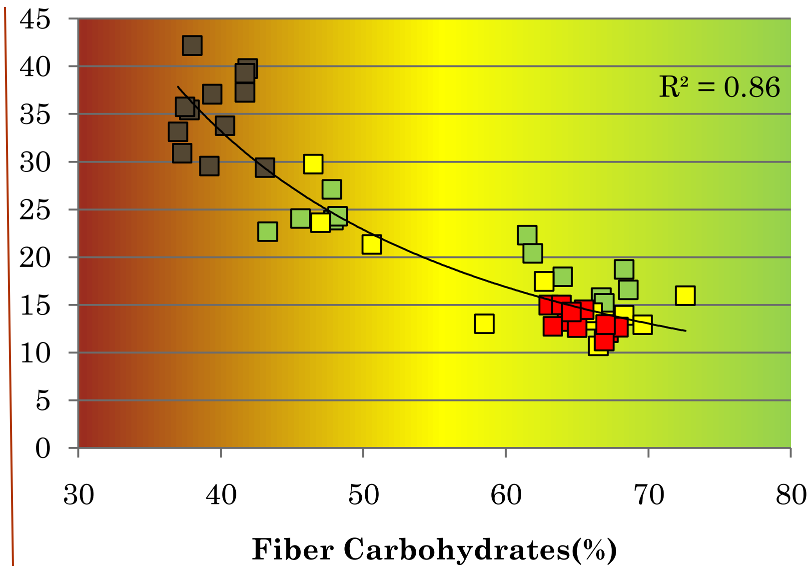
AVERAGE TIME TO IGNITION BY ATTACK CATEGORY

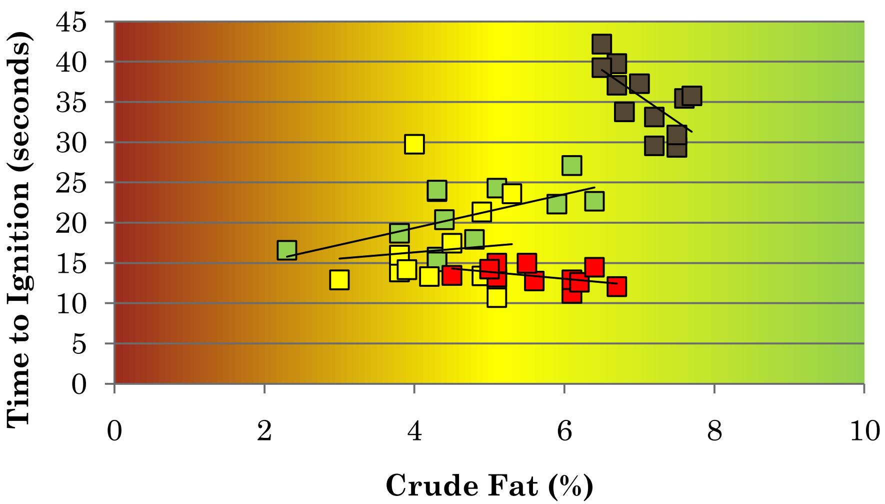


Tree Condition	Minimum time to ignition (seconds)	Maximum time to ignition (seconds)	Average (variation) of time to ignition (seconds)
Green	29.37	42.18	35.3 (4.1)
Attacked	15.14	27.1	20.7 (3.9)
Yellow	10.69	29.75	16.6 (5.6)
Red	11.2	14.99	13.3 (1.2)

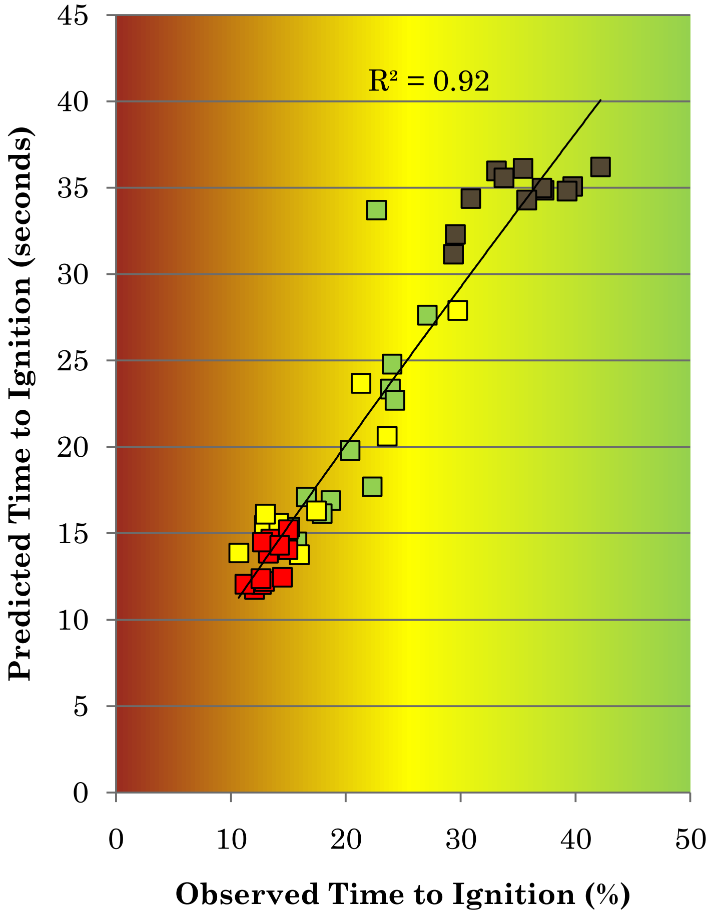
Moisture content, fiber carbohydrates and fats were all significant factors to foliage ignitability







Moisture content, Amount of Fat and Fiber Explain most of the variation in ignition times



- Increasing moisture contents increases time to ignition
- Increasing fiber or fats decreases time to ignition

From needles to trees

Rocky Mountain National Park Single Tree Torching Experiments

Impacts of Mountain Pine Beetle on LodgepolePine Fire Behavior

Nate Williamson, Mike Lewelling–RMNP
Monique Rocca, Bill Romme–CSU

Lodgepole Crown Status	Number of trees	% of crown that carried fire
alive, not attacked	5	0%
attacked, still green	3	0%
mixed red and green needles	1	100%
80-100% needles remaining	3	100%
60-79% needles remaining	2	50%
40-59% needles remaining	3	0%

Green tree, unattacked

Red tree, attacked 2 years ago

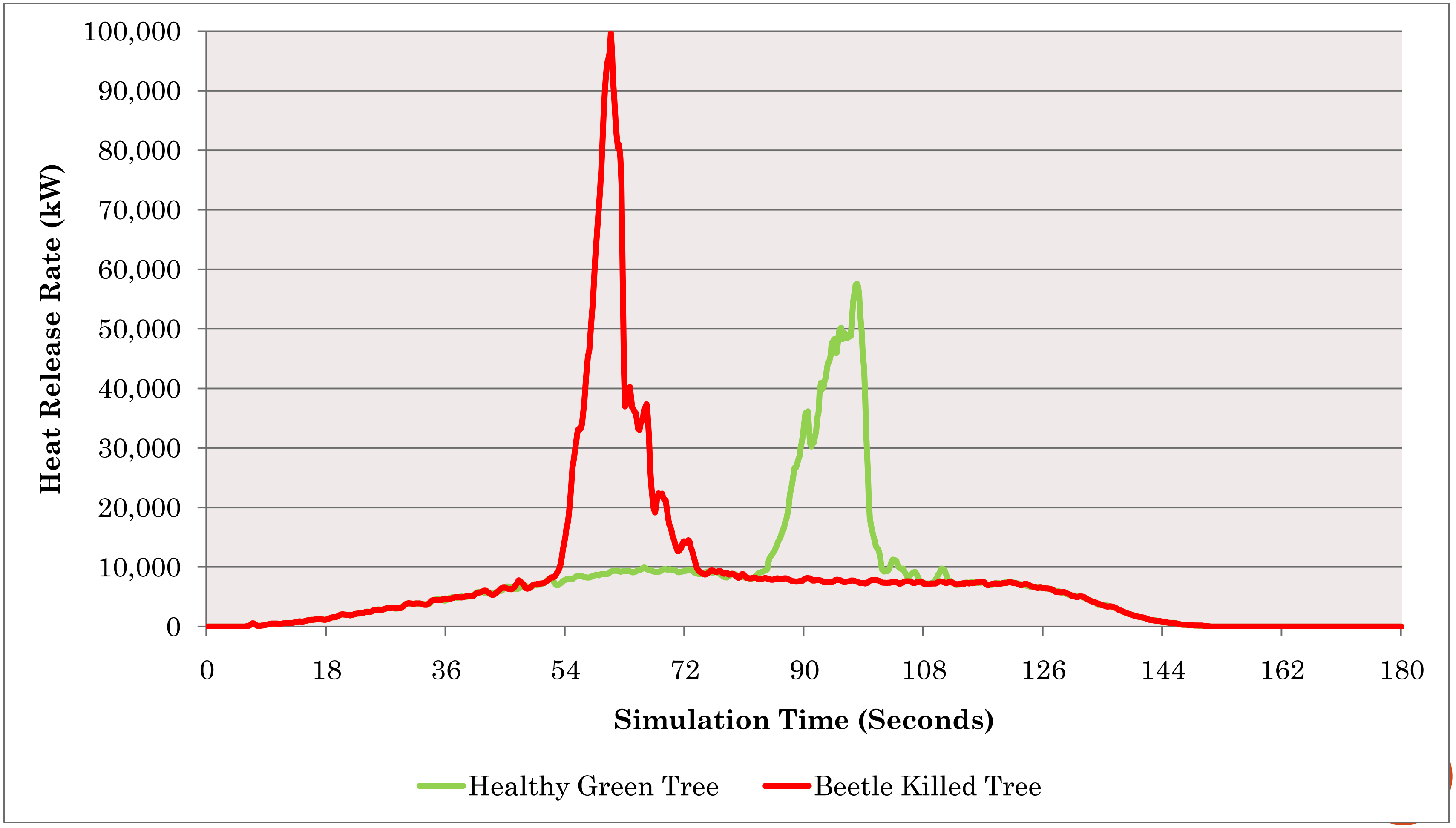
Red tree, attacked 3+ years ago

Simulating fire behavior in beetle-attacked trees

Three dimensional fire behavior modeling of bettle-killed trees using the Fire Dynamics Simulator

Insert Video #1

Heat Release Rate of Red Needle and Healthy Green Trees



Take home points

- Red needles are about ten times drier than green needles
  - Attacked trees can show moisture content and chemical changes before color change occurs
- Red needles ignite about three times faster than green needles
  - In the absence of structural changes, less heat is required to ignite the crowns from either below or above
- Increasing needle fiber or fat content will also increase flammability
- Red needle trees release more heat, faster and this may lead to increase spotting distance
- The structural changes of the fuels with time since attack have still not been completely described

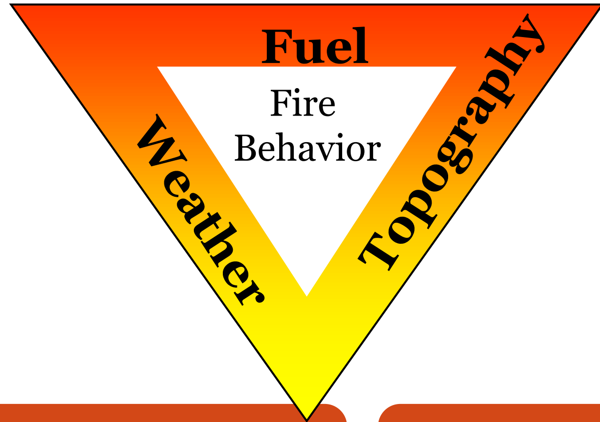
What does this all mean to fire behavior?

- Longer spotting distances
  - Spot fires up to a ¼ mile from a single torching tree have been observed in red needle trees and ½ mile from grey stage trees.
- Higher probability of ignition
  - More receptive fuels ahead of the approaching fire
- Larger safety zones required due to a larger potential net heat release.

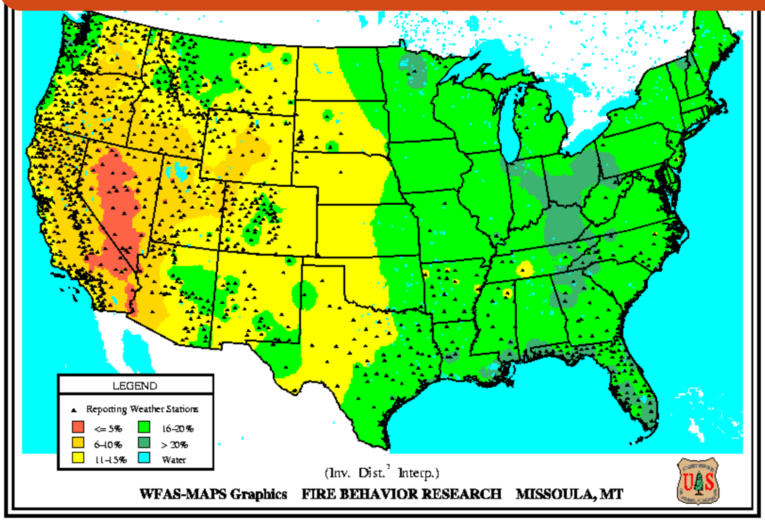
Mike Pritchard, BC Wildfire Mgt Br.

Fire number G40376, July 3rd, 2006
23 hectares

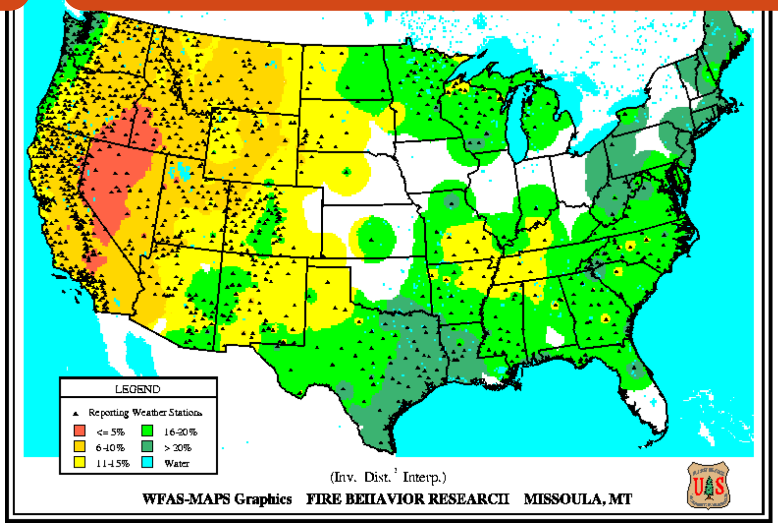
One Last thought:
If the foliage is so flammable, why hasn't it burned yet?



Heavy dead fuel moistures in 2010



Heavy Dead Fuel Moistures in 2007



- Weather has been a significant factor in reducing fire potential in Montana over the last few years.
- Changes in the fuel structure over time are also important but not well understood

Thank You and Questions?